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ABSTRACT

This report is one of a series from a project entitled Case Studies in Evaluating the Benefits and Costs of Mediated Instruction and Distributed Learning. This project examines the benefits and costs of the mediated learning system (MLS) courseware for remedial mathematics developed by Academic Systems Corporation. Comparisons were made at two universities that have been using the courseware for the regular classroom sections and MLS sections of the courses offered at each campus. Findings indicate that based on the evidence, it is not possible to reach a definitive conclusion regarding the learning outcomes of MLS versus classroom instruction. This report provides information on the implementation of MLS courseware for remedial mathematics, benefits of MLS student learning outcomes, and the costs of MLS courses compared to regular classroom costs. (Contains 12 tables and 9 charts.) (ASK)

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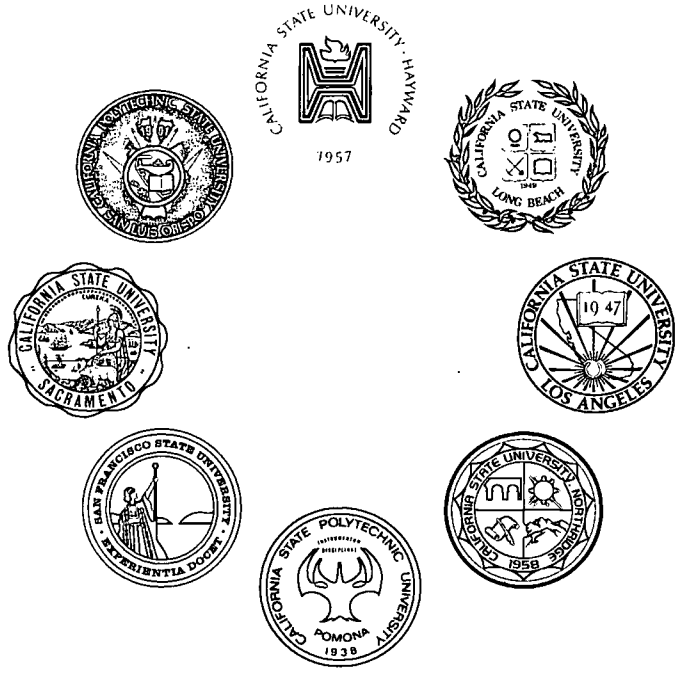
ED 427 965

# Courseware for Remedial Mathematics: A Case Study in the Benefits and Costs of the Mediated Learning System in the California State University

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This report is one of a series from a project entitled *Case Studies in Evaluating the Benefits and Costs of Mediated Instruction and Distributed Learning*. The project is funded through a Field-Initiated Studies Educational Research Grant by the National Institute on Postsecondary Education, Libraries, and Lifelong Learning, Office of Educational Research and Improvement, U.S. Department of Education with additional funding provided by Information Resources and Technology in the Chancellor's Office of the California State University. The project is jointly sponsored by the California State University, the National Learning Infrastructure Initiative of EDUCAUSE, and the State Higher Education Executive Officers. Grant Award No. R309f60088. 1998

Frank Jewett, Project Director
Information Resources and Technology
Chancellor's Office, California State University
P.O. Box 3842, Seal Beach, California 90740-7842
(562) 985-9156
e-mail: frank_jewett@calstate.edu
project web page: www.calstate.edu/special_projects/



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# Acknowledgments

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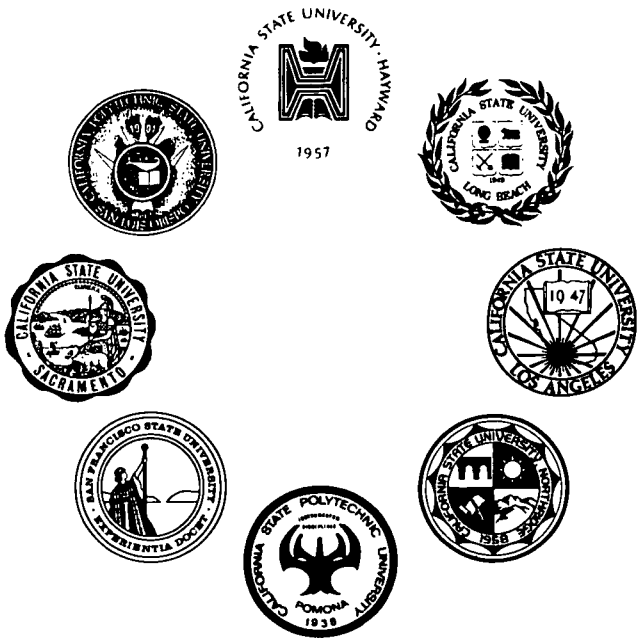
Since 1994 two CSU campuses have been using the mediated learning system courseware for remedial mathematics developed by Academic Systems Corporation. In 1995 six additional campuses became involved. The CSU effort to evaluate the courseware originated in spring 1996 with a request from the Provosts/Vice Presidents for Academic Affairs. The evaluation effort was overseen by an ad hoc committee chaired by Margaret Hartman, Provost and Vice President for Academic Affairs at CSU Los Angeles. The committee had representatives from each of the eight participating CSU campuses: Hayward - Kevin Callahan and Kathy Hann, Long Beach - Demos Arsenidis, Los Angeles - Marshall Cates, Northridge - Roberta Madison and Elena Marchisotto, Pomona - Richard Robertson and Donald Bell, Sacramento - Roberta Gehrmann, San Francisco - Newman Fisher and Bob Marcucci, and San Luis Obispo - Tom Hale and Glenn Irwin.

The project director gratefully acknowledges the efforts of the ad hoc committee chair and its members for their contributions to this study. Marshall Cates, Professor of Mathematics at CSU Los Angeles, provided a very useful paper on both the earlier implementation efforts and follow-up studies on the performance of students in later courses in mathematics that is incorporated as part of this report. Jack Fraenkel, Professor of Education at San Francisco State University, provided a report and the data that were used to summarize the performance of the students in the courses across the eight campuses. Support, assistance, and advice were also provided by members of the benefit cost project's Steering, Review, and Oversight Committee: Tony Bates, Director of Distance Education and Technology, University of British Columbia; Dennis Jones, President of NCHEMS; Jim Mingle, Executive Director of SHEEO; and Tom West, Assistant Vice Chancellor for Information Resources and Technology, CSU Chancellor's Office.

# Courseware for Remedial Mathematics: A Case Study in the Benefits and Costs of the Mediated Learning System in the California State University




## Summary, Findings, and Conclusions

1. Since 1994 California State University, Los Angeles (Cal State LA) and California Polytechnic State University, San Luis Obispo (Cal Poly) have been using the mediated learning system (MLS) courseware for remedial mathematics developed by Academic Systems Corporation. Both campuses have undertaken various evaluation studies.
2. Academic Systems' courseware was chosen at the time because it was the most sophisticated multimedia program available. It is highly interactive and provides several layers of student feedback. The MLS comes with a management system that captures student responses to questions and records time on task, thus allowing the instructor to monitor each student's progress. (The MLS courseware that was implemented runs in on-campus computer labs. A new version of the courseware is now accessible through the Internet.)
3. By 1996 six additional CSU campuses at Hayward, Long Beach, Northridge, Pomona, Sacramento, and San Francisco had also begun implementation of the MLS courseware.

## Benefits: Comparative Learning Outcomes

4. Cal Poly has adopted the MLS for all of its remedial mathematics courses. The courseware is available in a 60-station computer lab where the student work is overseen by graduate assistants under the direction of a faculty member.

5. Cal State LA has adopted the MLS for the remedial coursework provided to the most mathematically challenged students. A three-year evaluation of the MLS at Cal State LA contains the following summary statements:

   (a) As a replacement for regular classroom instruction the MLS courseware has the most benefit for those students who need remediation the most, where they can take advantage of the flexibility to repeat a lesson as often as needed.

   (b) The MLS courseware is not superior for all remedial students nor is there any indication that it is inferior.

   (c) An instructor is still essential for the MLS version of the remedial courses both as a motivating influence and as a personal contact for the students.

   (d) From a resource perspective the MLS allows larger section sizes without a loss of student performance.

   (e) Other potential benefits include: more flexible use of student time compatible with more time on task, more instructional support outside of classroom time, completion of course on a shortened time schedule, more convenient and user friendly for ESL students, longer retention of the material, and availability of Internet access to MLS supporting distributed instruction to off-campus locations.

6. An evaluation of learning outcomes in the remedial mathematics courses at the eight campuses was undertaken in fall 1996 at the request of the CSU Provosts/Vice Presidents for Academic Affairs. Over 4,500 students were enrolled in the courses; approximately 34 percent were enrolled in the MLS sections, 66 percent in regular classroom sections.

7. The MLS courseware was employed differently across the campuses. In some cases the MLS was used to supplement the regular weekly scheduled course meetings, in others it was an integral part of the course in the sense that its use replaced some, but not all, of the regular class meetings; at some sites, the MLS was used to essentially replace the regular class meetings and become the principal mode of providing the instruction. For all campuses, even if the entire course was scheduled to be delivered using the courseware, instructors would still call groups of students out of the lab for short "chalk talks" on particular topics as the need arose.

8. Two levels of remedial mathematics courses were evaluated, elementary and intermediate. Learning outcomes are measured by course passing rates and the percent of students completing the course with a final score of 70 or better. Comparisons of learning outcomes were made for the regular classroom (control) sections and the MLS (experimental) sections of the courses offered at each campus.

9. The course passing rate in the elementary course favored the MLS sections over the classroom sections at all of the seven sites where control sections were offered. The difference was statistically significant at only one site.

10. The percent of elementary level students with a final score of 70 or better was in favor of the MLS sections at four of the seven sites; one of these differences was statistically significant. Two of the three differences in favor of the classroom sections were statistically significant.

11. The course passing rate at the intermediate level was in favor of the MLS at four of six sites; one of these differences was statistically significant. Of the two sites where the difference favored classroom sections, one was statistically significant.

12. The percent of students with a final score of 70 or better at the intermediate level was in favor of the MLS sections at three of the six sites; none of the differences were statistically significant. Two of the three differences that favored the classroom sections were statistically significant.

13. Based upon this evidence it is not possible to reach a definitive conclusion regarding the learning outcomes of MLS as compared to classroom instruction.

    (a) At Cal State LA there is evidence that MLS improves the passing rates for the most mathematically challenged students who can benefit from a substantial amount of drill and practice.

    (b) In the seven-campus study there is weak evidence that the MLS improves passing rates in the elementary courses, but there is no evidence that it improves passing rates in the intermediate course or that it increases the percentage of students receiving a final score of 70 or better at either level. To the extent MLS improves passing rates, and reduces drop out rates, campuses benefit by generating more FTE and related funding.

    (c) Other benefits that may accrue to MLS include providing students with an introduction to the use of the computer as a learning tool, a more user-friendly learning situation for ESL students, and the potential to deliver courses to off-campus sites.

## Cost Comparisons

14. Certain basic patterns emerge from the comparison of the cost estimates for the two instructional modes:

    (a) At the lower levels of annual course enrollment, the costs of the MLS version of the course always exceed those of the classroom version. This occurs because of the fixed costs associated with the MLS course including the license fee and the costs of establishing and operating the initial MLS lab.

    (b) The incremental (or marginal) costs of additional enrollments in the MLS course tend to be less than those for the regular classroom course (assuming instructor pay rates for the different course sections are the same). This result occurs because the MLS fee revenue offsets some of the course's staffing cost. Incremental costs are also reduced to the extent average enrollment in the MLS sections is increased.

    (c) Once enrollment grows to the capacity of the MLS lab, an additional lab must be added causing a step-up in MLS costs.

15. At the current levels of campus enrollments in remedial mathematics courses (ranging between 300 and 1,500 students per year), the estimated direct costs of the MLS course exceed the costs of offering the instruction to the same number of students in the classroom course. For the case where MLS and classroom sections sizes are both equal to 30, a cost model developed based upon "typical" campus data shows a crossover (or breakeven) enrollment for the MLS exceeding 2,500 students per year.

16. However, because the marginal costs of the MLS course tend to be less than those of the classroom version, with sufficient levels of annual enrollment and the appropriate combination of cost and fee factors, the costs of MLS can be less than the costs of classroom instruction.

17. The two CSU campuses with the longest experience with the MLS have demonstrated cost savings by increasing section size without an increase in faculty workload (because the MLS is the main source of instructional materials) and without a reduction in the quality of student learning outcomes.

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# Background and Context

The California State University consists of twenty-two campuses located throughout the state.[1] The campuses enroll over 344,000 students and offer degrees in over 200 subject areas. The CSU system includes urban institutions serving large, primarily local, inner-city populations as well as suburban and rural institutions drawing their enrollments from throughout the state. Undergraduate students are admitted who are in the upper one-third of the high school graduating class or who transfer as upper division students from community colleges.

The CSU has programs for testing the proficiency of entering undergraduate students in English (started in 1977) and mathematics (1983). Students who fail the proficiency examinations are placed in remedial courses in the first term of their enrollment. Students who do not make adequate progress in their remedial work are expected to enroll elsewhere. The number of freshman students requiring remedial courses became a source of systemwide concern in the 1990s (typically over 50 percent of incoming freshmen fail the entry level mathematics examination). The CSU is currently operating under a Board of Trustees' resolution adopted in 1997 to reduce the percent of students requiring remedial work in mathematics as follows: to 42 percent by year 2001, to 26 percent by year 2004, to 10 percent by year 2007 (a similar provision is in place for English).

This case study report is based upon the use of multimedia courseware developed by Academic Systems Corporation to provide instruction in remedial and developmental mathematics. Their Mediated Learning System courseware (MLS) was developed to provide multimedia instructional materials in campus computer labs.[2] In fall 1994 two campuses, California State University, Los Angeles (Cal State LA) and California Polytechnic State University, San Luis Obispo (Cal Poly), began working with Academic Systems to implement the MLS as a component of their instruction for remedial mathematics. The intent was to exploit the potential of the computer to provide more flexibility for individual pacing, to better accommodate different learning styles, and to allow for increased time on task. It was also hoped that the introduction of more real life examples would improve student motivation to study elementary mathematics. Because many of the students at Cal State LA have English as a second language, there was also a need to identify ways to deal with the understanding of written mathematics.

Academic Systems' courseware was chosen because it was the most sophisticated multimedia program available. It emphasizes use of video and sound animated text. It is highly interactive and provides several layers of student feedback. The MLS comes equipped with a management system that captures student responses to questions and records time on task, thus allowing the instructor to monitor each student's progress and whether they are having any particular problems.

Cal Poly and Cal State LA are quite different. Cal Poly is a polytechnic university with programs in agriculture, architecture, and engineering. Located on the central California coast, it draws its students from throughout the state. Cal State LA is a comprehensive urban university with large programs in business, teacher preparation, and engineering. It is located in east Los Angeles and draws its students primarily from the local region, which has a high proportion of Hispanic, African American, and Asian households.

[1] A twenty-third campus, CSU Channel Islands, is under development.

[2] After this study had started, Academic Systems announced that the courseware "AcademicOnline" will be available for wide area networks and the Internet.

The CSU Chancellor's Office was also interested in computer aided instruction and provided financial assistance to both Cal State LA and Cal Poly to implement the MLS program. Both campuses agreed to conduct studies of the MLS courseware. Both campuses had been using regular lecture classes to teach remedial mathematics and both campuses had senior faculty who were interested in experimenting with computer mediated learning. Academic Systems was very helpful and worked closely with each campus to implement the MLS. Beginning in 1995, six other CSU campuses joined the experiment and reported varying degrees of success with the MLS as is discussed in more detail below.

## The Implementation of MLS Courseware for Remedial Mathematics at CSU Los Angeles

The following narrative describes the evolution of the use of the MLS at Cal State LA. It was extracted from a paper by Marshall Cates, Professor of Mathematics at Cal State LA.[3] The experience at Cal Poly was similar to that described below.

### 1994-95

"We started in fall 1994 with four sections of Introductory Algebra with a combined enrollment of 115 students. Our first concerns were: (1) how should the MLS be integrated with or used in our lecture classes and (2) how could we develop a consistent measure of student performance in the course.

"Concern #1 was approached by assigning different teaching strategies to various course sections as follows:

'bolt-on' – this involved the regular lecture classroom sessions in parallel with and in addition to the computer lab assignments;

'50/50' – half of the class time was spent in the regular classroom and half was spent in the lab working on the desktop computers;

'no lecture' – there were no regular classroom lectures, the instructor was available to answer questions and would occasionally arrange small group discussions;

'no instructor' – this most severe alternative was offered to students who could not get into either the regular classroom version or one of the other experimental versions of the course. Students in the 'no instructor' version were offered the opportunity to try the material on their own, using as much computer lab time as they wished. They were told that no one was going to monitor their progress, but if they needed help that they could contact an assigned instructor who had volunteered time to work with them.

"Concern #2 was answered by instituting a departmental final exam written by an instructor who was not teaching any of the classes. This exam was then team scored by all introductory algebra instructors. There were four experimental and eight control sections. Two instructors taught both experimental and control classes, which allowed for control of the instructor variable.

"During this time we (the course instructors and the departmental coordinator) started to meet as a team every other week where we discussed each section's performance regarding time on task and progress as measured by the number of quizzes completed. All sections were performing at about the same level in regard to average quiz scores.

[3] Marshall Cates, *A Case Study of the Use of Computers to Provide Remedial Instruction in Mathematics at California State University, Los Angeles*, January 1998.

"Table 1 summarizes the results at the end of the first quarter in terms of: (a) the percent of students who completed the course (i.e., who took the final) as an indicator of persistence in the course, (b) average score on the final (perhaps the best summary measure at a given point in time of a student's learning of mathematics), (c) percent who passed the final of those who took it, and (d) percent of students who passed the course. The percentage of students passing the final is calculated based upon the number who completed the course. The percentage passing the course is calculated based upon total course enrollments. Even if there were no drops between census date and the final date, the two percentages could still differ because course passing depends upon midterms and homework as well as the final exam score. Except for the no instructor model, the overall results suggested that the MLS students were doing about as well as those in the regular classroom version of the course. We were not disadvantaging the students nor were we out-pacing the traditional classroom model. Of course we didn't expect to make gains in our first trials.

**Table 1—Student Performance in Remedial Math Course Sections, Fall 1994**

| Type of instruction: | No. of students | Completed course | Final score | % who passed exam of those who took it | Passed course |
|---|---|---|---|---|---|
| Regular classroom | 268 | 85% | 63% | 62% | 69% |
| Bolt-on w/MLS | 31 | 84% | 60% | 62% | 61% |
| 50/50 w/MLS | 36 | 83% | 65% | 63% | 50% |
| No lecture w/MLS | 30 | 80% | 63% | 63% | 61% |
| No instructor w/MLS | 18 | 50% | 52% | 33% | 28% |
| Average MLS* | | 82% | 63% | 63% | 60% |

* Excludes data for the 'no instructor' option.

"By conducting student surveys we found that the no lecture and the bolt-on models were disliked by the students. In the bolt-on version, students felt that the extra lab time was a form of punishment. We tested the no instructor model three more times with some interesting results. In the fall of 1995, we offered a section of Intermediate Algebra with no instructor under the same conditions as before. We had a course completion rate of 30 percent with a 20 percent pass rate. In winter quarter 1996 we provided the no instructor section with extensive support material and students received a telephone call every week. The completion rate increased to 56 percent with a pass rate of 47 percent. In spring quarter we repeated the winter quarter material, but there were no telephone calls. The completion rate declined to 38 percent with a pass rate of 31 percent. Calling made a great deal of difference but not enough to put this option in competition with the others.

"During winter quarter, we offered one bolt-on section, one 50/50 lecture-lab section, one 30/70 lecture-lab section, and one section of no lecture. The results are shown in Table 2 where, again, student performance in the MLS sections compared favorably with that of the regular classroom sections.

**Table 2—Student Performance in Remedial Math Course Sections, Winter 1995**

| Type of instruction: | No. of students | Completed course | Final score | % who passed exam of those who took it | Passed course |
|---|---|---|---|---|---|
| Regular classroom | 195 | 80% | 63% | 60% | 65% |
| Bolt-on | 28 | 71% | 62% | 55% | 50% |
| 50/50 | 25 | 84% | 58% | 48% | 48% |
| 30/70 | 30 | 90% | 75% | 85% | 80% |
| No lecture | 23 | 78% | 58% | 44% | 74% |
| Average MLS | | 81% | 64% | 60% | 63% |

"In spring 1995 we experimented with reducing the amount of lecture, replacing it with more 'pull out' time. When a need was indicated by the management reports, each instructor was encouraged to pull the appropriate group of students off the computers into an attached conference room for a mini-lecture or student presented blackboard work. The no lecture model was losing favor. Both the instructors and the students wanted some instructor led discussion. We also found that with no lecture, students began to treat the class as an open lab, coming in late and leaving early. A ten-minute mini-lecture at the beginning and five-minute quiz at the end of each period were implemented to combat this tendency. Table 3 shows the results.

Table 3–Student Performance in Remedial Math Course Sections, Spring 1995

| Type of instruction: | No. of students | Completed course | Final score | % who passed exam of those who took it | Passed course |
|---|---|---|---|---|---|
| Regular classroom | 178 | 75% | 61% | 61% | 54% |
| 20/80 w/MLS | 19 | 74% | 62% | 57% | 53% |
| 30/70 w/MLS | 21 | 71% | 61% | 56% | 43% |
| 50/50 w/MLS | 31 | 71% | 61% | 59% | 48% |
| No lecture w/MLS | 12 | 58% | 49% | 43% | 25% |
| Average MLS | | 71% | 60% | 56% | 45% |

"By the end of 1994-95 it appeared that student performance in the MLS sections was about equivalent to that in the lecture sections, we had done no harm. In addition, student surveys showed a high level of support for the MLS sections, with praise for the flexibility of working on Saturdays. The surveys also identified an unexpected benefit in terms of computer literacy. Many students commented to the effect that now they had taken a 'computer class' they would not be afraid to take another. We had never considered the course to be a 'computer class' but for many of these students the course apparently represented their first experience with actually operating a computer for a practical purpose over an extended period of time.

"We also settled upon a 20 to 30 percent share of lecture time as our standard delivery mode. We had not found a superior way to use the mediated learning process, but instructors felt that we were making progress, and I felt that we hadn't tried all that we could. Luckily, I had the support of the senior administrators who had never demanded that I show immediate results, but who were always interested in what we were doing.

## 1995-96

"In the fall of 1995 additional MLS courseware became available for Intermediate Algebra. This allowed computer coverage of all of our remedial mathematics courses. Three strands of remediation were now offered. Introductory Algebra, Intermediate Algebra, and Intensive Learning Experience (ILE - this consists of a one-year course that covers both Introductory and Intermediate Algebra for students who scored in the lowest quartile of the entry level mathematics examination).

"We formalized some of our studies and introduced a pre-test so that we could measure growth and control for the variable of initial student preparation. As Table 4 shows, the MLS sections were superior to the regular classroom method for the ILE sections, our lowest level of mathematics.

**Table 4–Student Performance in Three Levels of Remedial Math Sections, 1995-96**

| Type of instruction: | No. of students | Completed course | Final score | % who passed exam of those who took it | Passed course |
|---|---|---|---|---|---|
| ILE - regular classroom | 379 | 83% | 53% | 39% | 47% |
| ILE - MLS | 127 | 86% | 51% | 44% | 54% |
| Intro. Alg. - regular classroom | 937 | 81% | 65% | 57% | 61% |
| Intro. Alg. - MLS | 171 | 80% | 65% | 59% | 53% |
| Intermed. Alg. - regular classroom | 709 | 79% | 60% | 57% | 57% |
| Intermed. Alg. - MLS | 153 | 81% | 66% | 59% | 57% |

"The MLS courseware as implemented at Cal State LA worked best at the lowest level (ILE), for students who needed to review material over and over again, and at the highest level (Intermediate Algebra), where students could take advantage of the option to speed ahead when all that they needed was to review a section.[4] Based upon final exam scores, there did not seem to be an advantage for the Introductory Algebra course. (The difference in the pass rates for Introductory Algebra was statistically significant and favored the regular classroom version of the course.)

"Shifting the ILE sections to MLS offered the ability to double average section size (because the instructors could rely upon the courseware to provide the bulk of the actual instruction) while keeping performance equivalent, at least. This saving, in terms of course staffing costs, essentially offset the cost of the MLS license. Shifting more students in Intermediate Algebra to the MLS format offered no cost advantage as average section size remained the same.

"In order to replace graduating faculty (graduate teaching associates) and to train new graduate students who had never taught before, we started a process of team teaching classes in the fall. New instructors were teamed with experienced instructors for the fall quarter. In subsequent quarters, these new faculty began teaching their own sections of the course.

[4] The differences in the ILE and Intermediate Algebra pass rates were not statistically significant at the 5 percent level, however.

### 1996-97

"During 1996-1997 we continued the team teaching and we continued to use MLS for some of the introductory and intermediate sections. During the year we experimented to see if we could use the courseware to allow students to proceed at different paces. Based upon previous experience we had an indication that 'self-pacing' in effect resulted in 'no pacing,' but we decided to try again. Eleven students were allowed to continue into the summer to finish their one-year sequence. I consider this experiment to have been a failure. Several students took the opportunity to take more time but this had no effect upon overall course completion rates.

"Beginning in fall 1996 we adopted the MLS in all the ILE sections. Table 5 compares the experience of all the classroom ILE sections in 1995-96 with the MLS sections in 1996-97. Since ILE is a one-year, three-course sequence, the completion rate is based upon the enrollment in the first course (Math 81) and the number of students who completed the third course (Math 83). The difference in the completion rates shown in Table 5 is in favor of the MLS courseware and is statistically significant at the 1 percent level. Given that the regular classroom sections were designed for a class size of 15 while the MLS sections were designed for 30, the MLS approach was clearly successful.

**Table 5–Performance of ILE Students in Regular Classroom Sections (1995-96) and MLS Sections (1996-97)**

| Type of remediation: | Students starting Math 81 | Students successfully completing the sequence | Percent completing the sequence |
|---|---|---|---|
| 1995-96<br>*Regular classroom*<br>Math 81-82-83 | 187 | 38 | 14.6% |
| 1996-97<br>*MLS*<br>Math 81-82-83 | 224 | 89 | 39.7% |

## Follow-up Studies

"Direct comparisons based upon test scores do not reveal the whole picture. We also studied what happens to students after they leave the remedial program. We conducted two studies.

"The first study, summarized in Table 6, was a 'forward tracking study' that tracked all remedial students who had taken Elementary Algebra in fall 1994. We counted the number of quarters that had elapsed before these students completed the general education course (equivalent to College Algebra), the completion rate after 5 quarters (through spring quarter 1996), and average GPA in the general education course. Fall 1994 was our first quarter for using the MLS

and, therefore, we were least experienced with it. At the time the study was done, however, no later quarter would have allowed enough time to obtain a sufficiently large proportion of students who had completed the general education course. The MLS students in the sample had a slightly lower completion rate (the difference between the two rates was not significant at the 5 percent level), a slightly shorter time to completion, and a slightly lower GPA.

**Table 6–Performance of Remedial Students in General Education Course**

| Remedial students who took Elem. Alg. fall 1994 | Regular classroom | MLS |
|---|---|---|
| 383 | 268 | 115 |
| No. of students completing general education | 101 (38%) | 39 (34%) |
| Average quarters to complete general education | 3.82 | 3.74 |
| Average GPA in general ed. | 2.53 | 2.38 |

"The second study involved tracking all enrollments in the general education course in winter quarter 1997 backwards to see how each student had qualified for the course. This 'backward tracking study' had two advantages. First, we are able to make comparisons with students who didn't need remediation and, second, we were not dealing with a truncated population. In the forward tracking study shown in Table 6, more than half of the students in the initial remedial population are not available for the follow-up comparisons, whereas in the backward tracking study every student in the initial population is accounted for in the comparison population. Table 7 shows the categories of students by type of remediation, if any, and their average GPAs in the general education course. The count of remedial students in the table includes those who needed only one remedial course (as distinct from the ILE students who needed three courses). Two results are suggested by the table: students who required a remedial course do not do as well in the general education course as students who did not require a remedial course, and the remedial students who took the MLS sections performed slightly better than those who took the regular classroom sections.

Table 7–Performance of All Students in the General Education Course, Winter 1997

| Type of remedial instruction: | Number of students | Average GPA in the general education course |
|---|---|---|
| Regular classroom | 353 | 1.87 |
| MLS | 29 | 1.94 |
| None | 633 | 2.39 |

"We are currently starting to use a new version of the MLS courseware that provides access over the Internet. Initially our goal is to reduce the amount of open lab access time that must be scheduled and replace it with general lab access and home access. Eventually we hope to evolve a program that will reduce the amount of time a student needs to spend on campus. There are several obstacles. First and foremost is student study habits that are overly reliant upon the rhythm of two or three weekly class meetings. Second is the need to provide students with convenient access for interaction with an instructor from a distance.

## Summary of Experience with Implementation at Cal State LA

- "As a replacement for regular classroom instruction the MLS courseware has the most benefit for those students who need remediation the most, where they can take advantage of the flexibility to repeat a lesson as often as needed.
- The MLS courseware is not superior for all remedial students nor is there any indication that it is inferior.
- An instructor is still essential for the MLS version of the remedial courses both as a motivating influence and as a personal contact for the students.
- From a resource perspective the MLS allows larger section sizes without a loss of student performance.
- Other potential benefits include: more flexible use of student time compatible with more time on task, more instructional support outside of classroom time, completion of course on a shortened time schedule, more convenient and user friendly for ESL students, longer retention of the material, and availability of MLS on the Internet supports distributed instruction to off-campus locations."

# Benefits of MLS – Student Learning Outcomes

This section on learning outcomes is a summary of the reports from the eight CSU campuses participating in the study to evaluate Academic Systems Corporation's interactive mathematics courseware materials, the Mediated Learning System (MLS) during fall term 1996.

The CSU ad hoc committee, appointed to oversee the evaluation effort, met and agreed to report a common set of data elements for evaluating the impact of the MLS courseware on learning outcomes in the introductory and intermediate algebra courses. The data included an entry level measure of mathematical skills (the MDTP test) and exit level performance as measured by final exam scores, course grades, and course completion rates.

Because some of the campuses were just starting to use the MLS while others had 2-3 years of experience, it was decided not to identify campuses by name. For purposes of this report the campuses are labeled sites A through H. The number of course sections and total enrollments for both the MLS and classroom versions of the elementary and intermediate courses are shown in Table 8. At the elementary level, Site B had no regular classroom (control) type sections, Site C had 14 classroom compared to eight MLS (experimental), and Site F had two MLS sections compared to 17 classroom sections. At the intermediate level, Site A had three MLS sections and 13 classroom sections, Site B, again, had no classroom sections, Site C had no intermediate sections at all, and Site F had two MLS and 27 classroom sections. In total, almost 4,700 students were enrolled in 155 sections of elementary and intermediate remedial mathematics. Approximately 34 percent of the enrollments were in MLS sections, 66 percent in regular classroom sections.

## Learning Outcomes, Results at Eight Campuses

The MLS courseware was employed differently across the campuses. Some of the campuses had been using the MLS for several terms, some had just implemented it. Based upon the experience of the campuses that have been using the courseware for several terms, there is a learning period during which the course configuration is likely to be changed somewhat in response to the particular campus needs. One of the campuses that has used the MLS for several terms has adopted it for all of its remedial mathematics instruction.

In some cases the MLS was used entirely as a supplement to the regular weekly scheduled course meetings, in other cases it was used as an integral part of the course in the sense that its use replaced some, but not all, of the regular class meetings; at some sites, the MLS was used to essentially replace the regular class meetings and become the principal mode of providing the instruction. These different uses are summarized in the campus sections below where the amount of regular classroom time that was displaced by the courseware is estimated. For all campuses, even if the entire course was scheduled to be delivered using the courseware, instructors would still call groups of students out of the lab for short "chalk talks" on particular topics as the need arose. In most cases students were expected to spend time, in addition to the regularly scheduled class hours, in the MLS labs doing homework or otherwise using the courseware.

**Table 8–Number of MLS and Classroom Sections and Enrollments by Site and Course Level, Fall 1996**

| Sites/course levels | | MLS Sections Sections | MLS Sections Students | Classroom Sections Sections | Classroom Sections Students |
|---|---|---|---|---|---|
| Site A | elementary | 3 | 88 | 4 | 101 |
| | intermediate | 3 | 80 | 13 | 337 |
| Site B | elementary | 5 | 265 | 0 | 0 |
| | intermediate | 5 | 253 | 0 | 0 |
| Site C | elementary | 8 | 225 | 14 | 475 |
| | intermediate | 0 | 0 | 0 | 0 |
| Site D | elementary | 3 | 90 | 3 | 129 |
| | intermediate | 4 | 118 | 5 | 210 |
| Site E | elementary | 4 | 70 | 5 | 75 |
| | intermediate | 5 | 83 | 4 | 67 |
| Site F | elementary | 2 | 46 | 17 | 415 |
| | intermediate | 2 | 55 | 27 | 931 |
| Site G | elementary | 3 | 80 | 3 | 95 |
| | intermediate | 3 | 64 | 3 | 118 |
| Site H | elementary | 2 | 47 | 2 | 81 |
| | intermediate | 2 | 50 | 1 | 39 |
| Total | elementary | 30 | 911 | 48 | 1,371 |
| | intermediate | 24 | 703 | 53 | 1,702 |
| Total | all levels | 54 | 1,614 | 101 | 3,073 |
| | Total enrollments | | 4,687 | | |
| | Total sections | | 155 | | |

In addition to the number of course sections and census date enrollments, each site reported scores on the CSU-UC Mathematics Development Project Test (MDPT), which was used as a pre-test for students enrolled in both elementary and intermediate sections of the courses. Four outcome results were reported in the original evaluation study:[5] the number of enrollees who took the final (a measure of attrition), average final exam scores, number of enrollees passing the course, and the number who received a final score of 70 or better. The site specific data reported in Tables 9A through 9H below include: average MDPT scores, average section size, total enrollment in the experimental and control sections, percent of students passing the course, and percent taking the final who received a score of 70 or better.

[5] See J. R. Frankel, *Academic Systems Corporation Interactive Mathematics Evaluation of Learning Outcomes*, San Francisco State University, June 1997.

## Site A

Approximately 75 percent of the course work was based upon the MLS courseware at this campus. All sections were taught from a common syllabus. Course pacing was standardized. All students took instructor-designed, coordinator-approved weekly quizzes and two midterms. Daily homework was required and graded. The regular classroom/lecture (control) sections were scheduled for four hours of lecture/discussion per week with some minimal use of small groups at the discretion of the instructor. The MLS (experimental) sections had one hour of lecture per week in a classroom and three hours of class time on-line supplemented as necessary with one-on-one or small group instruction.

*Elementary*–In terms of the MDPT pre-test scores the two groups were essentially equal. Eighty percent of the MLS students successfully completed the course compared to 71 percent in the regular classroom sections, a differential pass rate for these groups of over 12 percent.[6] The MLS group also had a higher rate, by about 11 percent, of passing the course with final scores of 70 or better. Neither of these differences was statistically significant from zero at the 5 percent level (i.e., neither of the "z" values was greater than 1.96).

*Intermediate*–The pass rate for the MLS sections was over 7 percent higher than for the classroom sections but the difference was not statistically significant. The lecture sections had a substantially higher proportion of final scores of 70 or better (negative percentages shown in the table indicate differences in favor of the classroom sections), and, in this case, the difference was statistically significant and in favor of the classroom group.

**Table 9A–Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference[7] | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 70 | 69 | | |
| Avg. section size | 29 | 25 | | |
| Total enrollment | 88 | 101 | | |
| Percent passing | 80% | 71% | +12.7% | No (1.31) |
| Percent passing w/ score of 70 or better | 60% | 54% | +11.1% | No (0.89) |
| *Intermediate* | | | | |
| Avg. MDPT score | 57 | 59 | | |
| Avg. section size | 27 | 26 | | |
| Total enrollment | 80 | 337 | | |
| Percent passing | 59% | 55% | +7.3% | No (0.53) |
| Percent passing w/ score of 70 or better | 15% | 30% | -50.0% | Yes (2.74) |

[6] The difference between the two rates is 9 percentage points (80-71). The relative difference, using the classroom rate as the base, is 12.7 percent (9/71 = 0.127).

[7] The percent difference in this series of tables is calculated as discussed in the previous footnote. A positive percent difference indicates the MLS value is greater, a negative difference indicates the classroom value is greater.

## Site B

The MLS courseware constituted approximately 95 percent of the course work at this campus. The campus has used the MLS materials for several terms and has adopted it for all remedial mathematics instruction in its two courses. All courses are three quarter units and are taught by graduate assistants under the supervision of a part-time faculty member. All instruction occurs in a large (60-station) computer lab constructed for the courses. Except for group orientation, occasional small group sessions and explanations, and one-on-one or small-group sidebars, all work was done on-line.

The course pass rates and percent passing with final scores of 70 or better for this site compare very favorably with those at the other campuses. It should also be noted that the average MDPT scores at this site are in the upper range of those observed at other sites.

**Table 9B—Student Performance in MLS Sections**

| Course level | MLS |
|---|---|
| *Elementary* | |
| Avg. MDPT score | 71 |
| Avg. section size | 53 |
| Total enrollment | 265 |
| Percent passing | 73% |
| Percent passing w/ score of 70 or better | 73% |
| *Intermediate* | |
| Avg. MDPT score | 57 |
| Avg. section size | 51 |
| Total enrollment | 253 |
| Percent passing | 74% |
| Percent passing w/ score of 70 or better | 79%* |

* "Percent passing with a score of 70 or better" is calculated based upon number of students who took the final. This value can exceed "percent passing," which is based upon total students enrolled.

## Site C

A four-quarter unit elementary course was offered; there was no intermediate course. All of the course work in the MLS sections was based upon the MLS courseware. Lecture section students spend four hours in lecture/discussion classes. All instruction for MLS sections takes place in the computer lab where students receive approximately one hour of lecture/discussion and three hours on-line instruction per week.

Students in the lecture sections had a higher average score on the MDPT test but the MLS students passed the course at a 54 percent higher rate. The MLS students also did better on the final scores, earning grades of 70-plus at a 46 percent higher rate. Both differences were statistically significant.

**Table 9C—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 43 | 55 | | |
| Avg. section size | 28 | 34 | | |
| Total enrollment | 225 | 475 | | |
| Percent passing | 77% | 50% | +54.0% | Yes (6.81) |
| Percent passing w/ score of 70 or better | 51% | 35% | +45.7% | Yes (4.19) |

## Site D

All courses were three semester units. Lecture sections met in regular classrooms. The MLS courseware constituted approximately 95 percent of the MLS version of the courses. The MLS sections met in a computer laboratory and were assisted by instructors primarily on a one-on-one basis. All MLS section work was done on-line. All students took a common final examination.

The students in the intermediate MLS sections had higher MDPT scores. The passing rate and the percent passing with a score of 70 or better were higher for the MLS students in both the elementary and intermediate courses. Although the differences in all the ratios favored the MLS sections, none of the differences were statistically significant.

**Table 9D—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 68 | 67 | | |
| Avg. section size | 30 | 43 | | |
| Total enrollment | 90 | 129 | | |
| Percent passing | 86% | 81% | +6.2% | No (0.95) |
| Percent passing w/ score of 70 or better | 79% | 69% | +14.5% | No (1.60) |
| *Intermediate* | | | | |
| Avg. MDPT score | 52 | 46 | | |
| Avg. section size | 30 | 42 | | |
| Total enrollment | 118 | 210 | | |
| Percent passing | 70% | 60% | +16.7% | No (1.95) |
| Percent passing w/ score of 70 or better | 46% | 40% | +15.0% | No (1.12) |

## Site E

Both the classroom and MLS sections met four times per week for four units. The curriculum for both was paced and required in-class examinations. The MLS courseware constituted approximately 95 percent of the content in the MLS sections. The classroom sections enrolled 15-17 students and were taught as tutorials by three student assistants who were supervised by a part-time faculty member. The MLS sections enrolled 17-18 students and were taught in a 20-station computer laboratory by two graduate assistants supervised by a part-time faculty member. All work in the MLS sections was done on-line.

The MLS students in the elementary course had a slightly higher average MDPT score and course passing rate, but an 11 percent lower pass rate with final scores of 70 or better; neither of the latter two differences was statistically significant. The MLS students in the intermediate sections had slightly lower MDPT scores and a course passing rate 21 percent lower than the lecture students. This difference was statistically significant. The MLS students also had a higher rate of passing with final scores of 70 or better but the difference was not statistically significant.

**Table 9E—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 71 | 67 | | |
| Avg. section size | 18 | 15 | | |
| Total enrollment | 70 | 75 | | |
| Percent passing | 86% | 83% | +3.6% | No (0.50) |
| Percent passing w/ score of 70 or better | 58% | 65% | -10.8% | No (0.87) |
| *Intermediate* | | | | |
| Avg. MDPT score | 48 | 52 | | |
| Avg. section size | 17 | 17 | | |
| Total enrollment | 83 | 67 | | |
| Percent passing | 65% | 82% | -20.7% | Yes (2.32) |
| Percent passing w/ score of 70 or better | 31% | 30% | +3.3% | No (0.19) |

## Site F

All courses were three semester units. The classroom sections were scheduled three hours per week in a regular classroom. Use of the MLS courseware accounted for approximately 67 percent of the course work in the MLS sections. The MLS sections were scheduled one hour per week in a classroom and two hours in the computer lab.

The MLS students at both levels had slightly lower average MDPT scores, higher course passing rates, and a higher percent passing with final score of 70 or better. None of the differences were statistically significant.

**Table 9F—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 51 | 53 | | |
| Avg. section size | 23 | 24 | | |
| Total enrollment | 46 | 415 | | |
| Percent passing | 74% | 62% | +19.4% | No (1.54) |
| Percent passing w/ score of 70 or better | 64% | 55% | +16.4% | No (1.17) |
| *Intermediate* | | | | |
| Avg. MDPT score | 40 | 42 | | |
| Avg. section size | 28 | 34 | | |
| Total enrollment | 55 | 931 | | |
| Percent passing | 71% | 64% | +10.9% | No (1.08) |
| Percent passing w/ score of 70 or better | 64% | 55% | +16.4% | No (1.31) |

## Site G

All courses were four quarter units. The MLS courseware constituted approximately 95 of the content of the MLS sections. The students in the MLS sections spent four hours per week in a lab setting, students in the classroom version of the courses spent four hours per week in lecture discussion sessions. Students in the MLS sections were also expected to spend (an unspecified amount of) time in the computer lab.

At both course levels the MLS sections had lower average section enrollments, slightly higher MDPT scores, and higher course passing rates than the lecture sections. At both levels the lecture sections had a substantially higher passing rate with final scores of 70 or better. The difference in the passing rate for the elementary sections was not statistically significant. The difference in the passing rate at the intermediate level and the passing rate with a final score of 70 or more at both levels was statistically significant.

**Table 9G—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 69 | 64 | | |
| Avg. section size | 27 | 32 | | |
| Total enrollment | 80 | 95 | | |
| Percent passing | 73% | 60% | +21.7% | No (1.74) |
| Percent passing w/ score of 70 or better | 36% | 58% | -37.9% | Yes (2.88) |
| *Intermediate* | | | | |
| Avg. MDPT score | 45 | 41 | | |
| Avg. section size | 21 | 39 | | |
| Total enrollment | 64 | 118 | | |
| Percent passing | 68% | 53% | +28.3% | Yes (2.01) |
| Percent passing w/ score of 70 or better | 28% | 53% | -52.8% | Yes (3.30) |

## Site H

The MLS courseware constituted approximately 90 percent of the work in the MLS sections. All sections were for five semester units that required students to attend five hours per week. All sections required interactive learning. The non-MLS sections (control sections) relied upon collaborative learning/group problem solving approaches in combination with 10-15 minute instructor-led discussions with the entire class.

The elementary control sections enrolled an average of 41 students in a course taught by a graduate teaching associate assisted by two student tutors. The MLS sections enrolled an average of 24 students, all of whom were repeating the course. Topics not included in the MLS courseware were taught in classrooms the same way as in the control sections. Most of the MLS instruction occurred in the computer lab with occasional groupwork in an adjoining classroom.

The elementary MLS sections had substantially smaller average enrollments than the control sections. There was no difference between the MDPT scores. The MLS section had an 11 percent higher passing rate, but the control section had an 81 percent higher rate for students passing with a final score of 70 or better. This latter difference was statistically significant. The intermediate MLS sections had smaller average enrollments and lower average MDPT scores than the classroom sections. Both the pass rate and the percent with final score of 70 or better were substantially higher for the control sections but the differences were not statistically significant.

**Table 9H—Comparison of Student Performance in MLS and Lecture Sections**

| Course level | MLS | Regular classroom | Percent difference | Difference significant @ 5%? ("z") |
|---|---|---|---|---|
| *Elementary* | | | | |
| Avg. MDPT score | 35 | 35 | | |
| Avg. section size | 24 | 41 | | |
| Total enrollment | 47 | 81 | | |
| Percent passing | 40% | 36% | +11.1% | No (0.52) |
| Percent passing w/ score of 70 or better | 5% | 27% | -81.5% | Yes (3.09) |
| *Intermediate* | | | | |
| Avg. MDPT score | 48 | 53 | | |
| Avg. section size | 25 | 39 | | |
| Total enrollment | 50 | 39 | | |
| Percent passing | 38% | 54% | -29.6% | No (1.49) |
| Percent passing w/ score of 70 or better | 12% | 22% | -45.5% | No (1.24) |

## Student Performance Across Sites

Chart I provides a comparison of the course passing rates for the seven campuses that had both classroom and MLS versions of the elementary course. The data have been sorted by classroom passing rates in ascending order to facilitate the visual display. In all seven cases the MLS passing rate exceeds the classroom passing rate. The difference was statistically significant only for site C.

### Chart I–Passing Rates: Elementary

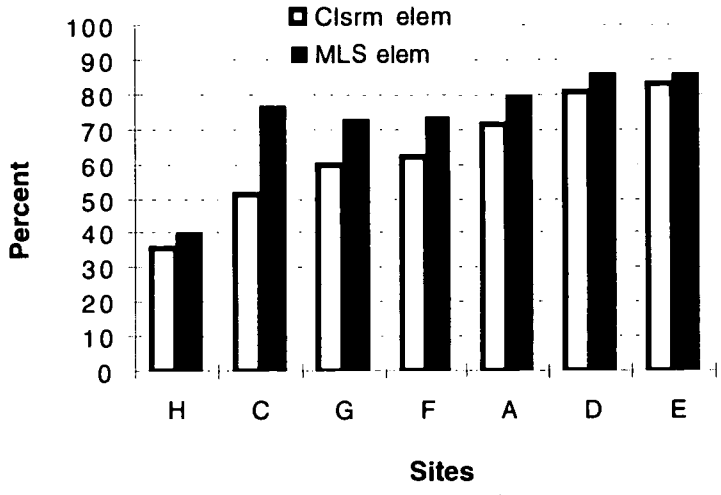
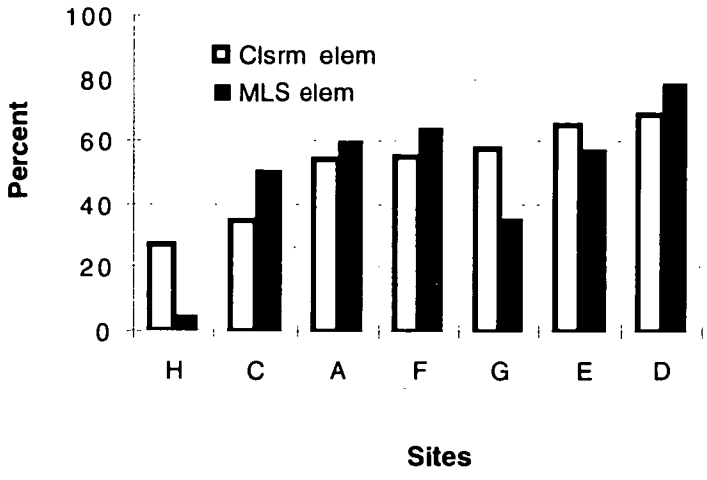



Chart II provides a comparison of the percent with a final score of 70 or better for the elementary course. Here the MLS sections did better than the classroom sections at four of the seven sites; the difference was statistically significant only at site C. Of the three sites where the differences favored classroom sections, those at sites H and G were statistically significant.

### Chart II–Percent w/Final Score of 70 or Better: Elementary



Charts III and IV provide data similar to Charts I and II for the six campuses that offered classroom and MLS sections of the intermediate course. In terms of course passing rates, as shown in Chart III, the MLS students did better at four of the six sites. The difference was significant (in favor of the MLS sections) only at site G. At the two sites where the passing rates favored the classroom students, the difference was statistically significant at site E.

In terms of passing rates with final scores of 70 or better, as shown in Chart IV, the MLS sections did better at three of the six sites but none of the differences were statistically significant. At the three sites where the passing rates with final scores of 70 or better favored classroom sections, the differences were significant at sites A and G.

**Chart III—Passing Rates: Intermediate**

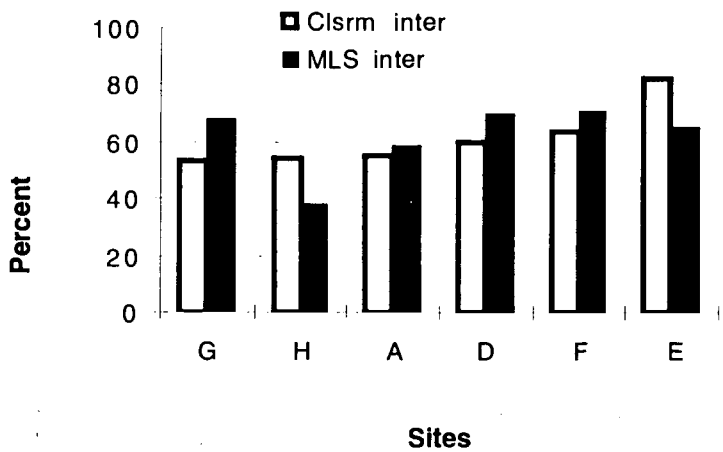
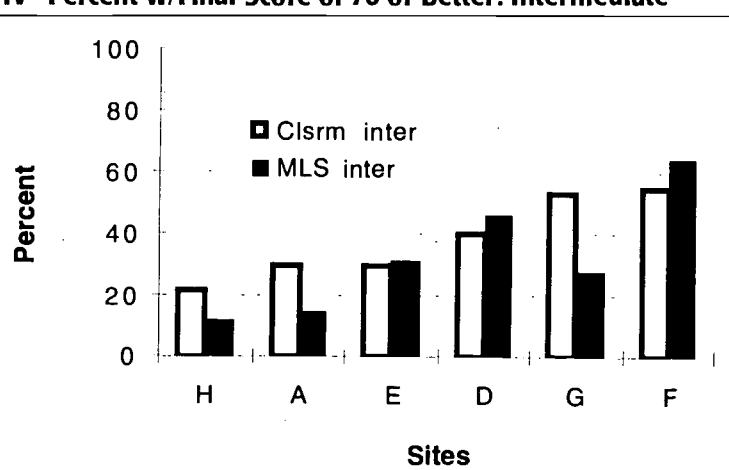



**Chart IV—Percent w/Final Score of 70 or Better: Intermediate**



Charts V and VI show the passing rate data associated with average MDPT scores. The hypothesis is that students with higher scores on the MDPT pre-test should have a higher probability of passing the course without regard to whether they were in a classroom or MLS section. The scatter of points representing the average MDPT scores and average passing rates should show a trend from the lower left to the upper right of the chart. To the extent the MLS materials systematically improve course passing rates, the MLS points should lie above the classroom points.

Both of these patterns are present for the elementary course as shown in Chart V. The positive correlation between MDPT scores and passing rates is most obvious for the classroom sections. This same pattern is less clear for the MLS sections (it is even less obvious if the single MLS point on the lower left of the chart is ignored). There is a tendency for the MLS passing rates to lie above the classroom passing rates, but the tendency is much stronger for the sections with low average MDPT scores. The implication is that the MLS is most beneficial to those students in the elementary course who are most challenged mathematically.

The patterns for passing rates in the intermediate course shown in Chart VI are more ambiguous. There is a very slight tendency for the MLS rates to lie above the classroom rates for given MDPT scores, but the pattern is contradicted by two outliers, a classroom passing rate above all others and an MLS passing rate below all others.

**Chart V—Pass Rates vs. MDPT Scores: Elementary**

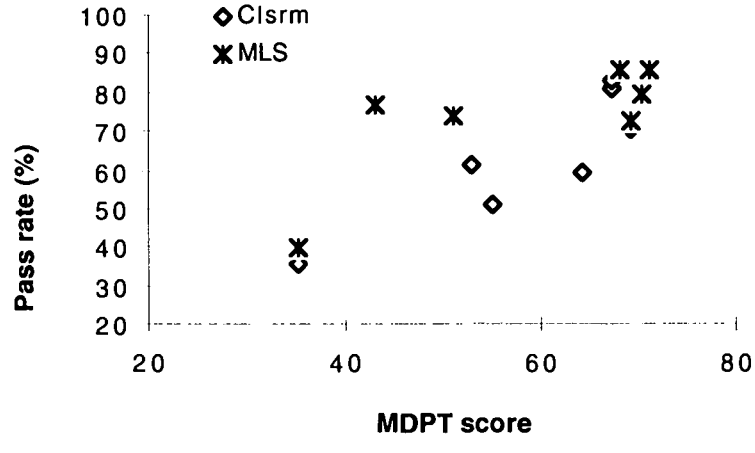
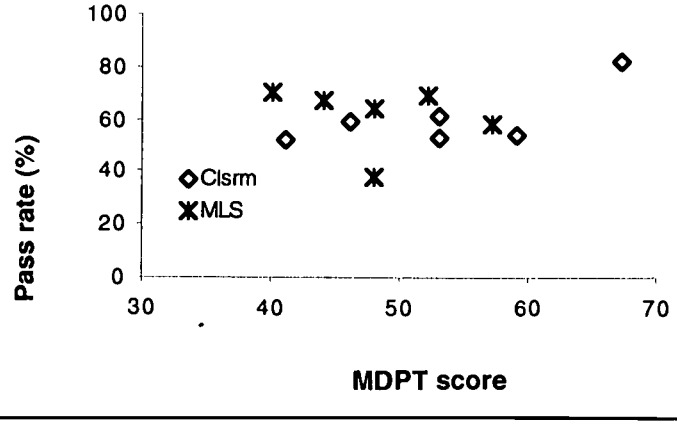



**Chart VI—Pass Rates vs. MDPT Scores: Intermediate**



# Costs of MLS Compared to Regular Classroom Costs

For purposes of developing campus cost estimates for MLS and regular classroom instruction the ad hoc committee agreed to report a set of data relating to the costs of the computer lab where the MLS courseware is available and the costs of staffing both the MLS and the lecture course. The results discussed below are based upon data provided by six campuses.

The MLS courseware has been implemented in different ways at different campuses. These differences lead to different costs. This is especially true in terms of laboratory monitoring costs and in terms of the fees charged students for the MLS workbooks (fee revenue is treated here as an offset against the costs associated with the MLS course). Section enrollments in the MLS version of the course varied between 15 and 50. In some cases enrollments were restricted because of existing computer lab capacity. In others, large labs had been specifically designed to allow the courseware to serve as the basis for a substantial amount of the actual coursework with instructors primarily responsible for monitoring student progress and intervening only as necessary.[8]

Costs of the MLS courses were estimated based upon three versions of a basic model that relates costs to annual course enrollments. The cost parameters of the model shown in Tables 10, 11, and 12 are based upon data supplied by the campuses. The basic cost model combines characteristics of the actual courses that were offered but does not exactly represent any specific course. The three versions of the model were based upon MLS computer labs designed for 20, 35 and 50 stations, a range that encompasses the actual enrollment levels observed across the campuses. The average section size for all the classroom sections offered was 30; this is the enrollment value used for the classroom sections in the three cost comparisons shown below.

The MLS version of the course requires that students have access to a multimedia laboratory where the courseware is available on a local area network (later versions of the MLS materials are available on the Internet). The capital costs of creating such a lab are detailed in the top panel of Table 10. These initial capital costs are converted to annual costs based upon estimates of useful lives of the various assets. The second panel of Table 10 shows lab monitor and maintenance estimates. The third panel shows the estimated annual costs for three different size labs.

[8] Cal State LA had experimented earlier with an MLS section without an instructor. It was concluded that this was not a feasible way to offer the course.

## Table 10—Estimated Costs for Mediated Learning System Lab

| Cost items | Initial cost | Useful life | Annual cost |
|---|---|---|---|
| **Capital costs:**[9] | | | |
| Computer workstation | @$2,000 | 4 years | $500 |
| Facility remodel | $15,000 | 25 years | $600 |
| Furniture | $10,000 | 10 years | $1,000 |
| Value of room | $90,000 | 30 years | $3,000 |
| **Operating costs:** | | | |
| Lab monitors | | | |
| 70 hrs./wk. @$10/hr. for 30 weeks | | | $21,000 |
| Lab maintenance | | | $2,000 |
| **Estimated annual costs for:** | | | |
| 20-station lab | | | $37,600 |
| 35-station lab | | | $45,100 |
| 50-station lab | | | $52,600 |

[9] These capital costs are estimated as though the lab was used exclusively for the MLS courses. If other courses could use the lab, e.g., on a 50-50 basis, then the lab costs should be reduced proportionately. For MLS courses with relatively small annual enrollments, such sharing represents a good way to reduce the lab costs.

Table 11 provides the elements for estimating the annual direct costs of both the MLS and the lecture versions of the course. The site license fee is a major component of the MLS cost. Section staffing costs are relatively low because of the use of part-time faculty to instruct the course (the same staffing costs are used for both the MLS and classroom sections). The lab cost for the MLS course is the estimated annual capital cost from Table 10 adjusted upward as the capacity of a lab is reached. For the MLS course a fee, representing the net revenue from the sale of the workbooks (supplied as part of the site license), is treated as an offset against expenses.

The capital cost of the classroom is based upon an estimate of $90,000 to construct and a 30-year useful life spread over an estimated capacity of 24 sections per room per year. A tutor/grading cost, estimated at $17.50 per student, is added to the classroom costs because several of the campuses used student assistants for this purpose.

**Table 11—Estimated Direct Annual Cost Elements for Remedial Mathematics**

| MLS version | Item |
|---|---|
| Site license | $72,500 |
| Section staffing | $2,400 |
| Lab costs | (see Table 10) |
| Less revenues | @ $35/student |
| **Classroom version** | |
| Section staffing | $2,400 |
| Estimated capital cost per section | $125 |
| Estimated tutor/grading cost per student (1.75 hrs./student @$10 per hour) | $17.50 |

Finally, lab capacity must be calculated because once the capacity of a lab is reached, an additional lab has to be added. The calculation, shown in Table 12, is based upon the assumption that a student enrolled in an MLS section will, on average, spend five hours per week in the lab. The 70-hour week represents the CSU's standard classroom schedule requirement of 8 a.m. - 10 p.m., five days a week. Labs could be available more than 70 hours per week by scheduling on weekends. (Scheduling during the summer months could also increase lab availability.)

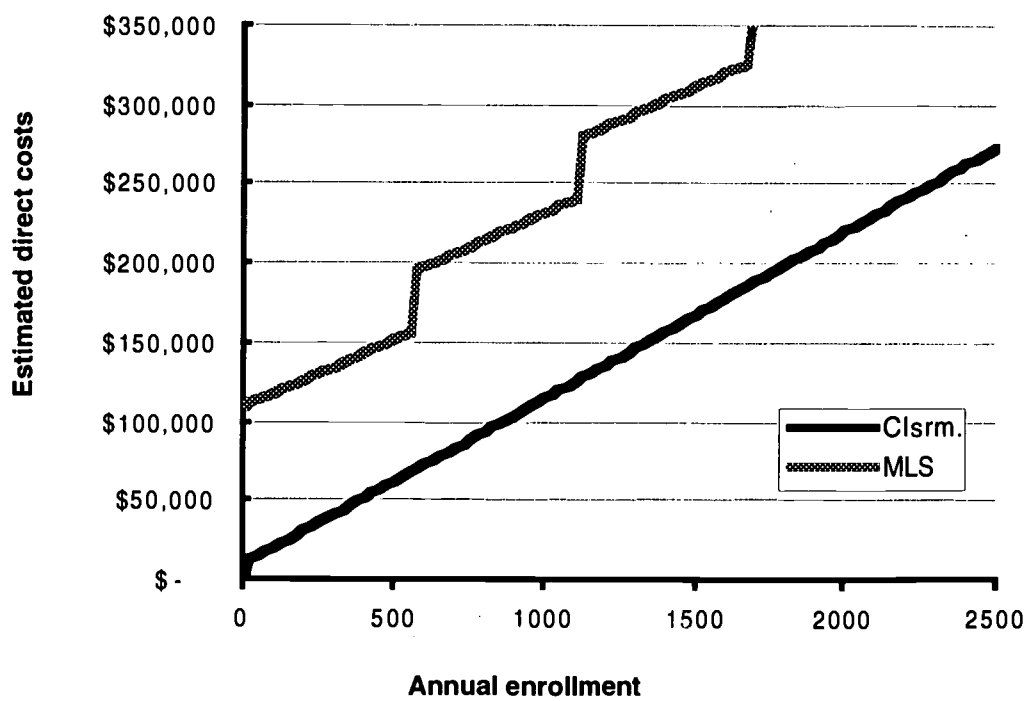
The combined cost estimates from Tables 10 and 11 are used to generate the graphs of the cost schedules relating estimated direct costs to annual course enrollments for both the MLS and lecture sections of the course. The lab capacity data in Table 12 are used to adjust the MLS cost upward when the capacity of a lab is reached. In actual practice the labs might be phased in (or shared with other courses) so that the "steps" shown in the graphs below might not have such sharp corners. Nevertheless, the general shape and position of the graph still provides a relatively good indicator for comparison purposes.

**Table 12—Estimated MLS Lab Capacity**

| Hours per week per student | Lab hours per week | Students per station per term | Students per station per year |
|---|---|---|---|
| 5 | 70 | 14 | 28 |
| | **Small lab** | **Intermed. lab** | **Large lab** |
| Stations per lab | 20 | 35 | 50 |
| Students per lab | 560 | 980 | 1,400 |

The Small Lab Case illustrated in Chart VII shows the situation where the MLS courseware is implemented in a lab that limits section enrollments below those of the classroom sections. [10] In this case the MLS course costs more than the classroom course at all levels of enrollment even though the incremental (or marginal cost) per student enrollee is less for the MLS course than for the lecture course (because the $35 workbook revenues offset some of the staffing costs). The MLS costs are always greater than the lecture costs because the capacity of the lab is reached before the MLS cost graph intersects the classroom cost graph. The additional lab costs shift the MLS graph in such a way that the MLS costs are always above lecture costs.

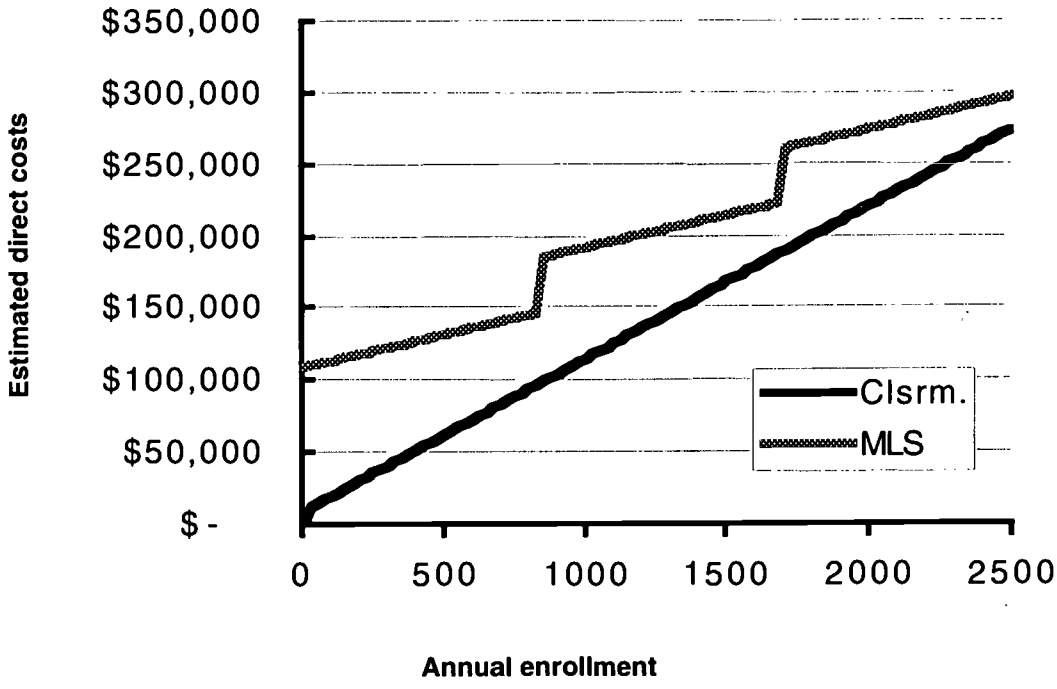
**Chart VII—Small Lab Case, MLS Section (Enrollment=20, Classroom Section Enrollment=30)**




[10] This reflects the experience of several of the campuses in the case study. It is likely the enrollment difference is the result of a start-up situation constrained by inadequate lab facilities rather than a policy decision to have lower section enrollments in the MLS course. It is a good example to model, however, because it illustrates an expensive implementation of the MLS technology.

The Intermediate Case shown in Chart VIII has the MLS lab section with an enrollment of 30,[11] the same as the classroom section size. Here the MLS incremental costs per student are lower than in Chart VII because of the larger section size. The two graphs are converging but the intersection occurs at an annual enrollment level above 2,500. (If MLS section size were 35, an intersection—a crossover or breakeven point—occurs at an enrollment of 2,000.) This is an important result to note because annual enrollments in the remedial mathematics courses average about 1,000 students across the campuses.

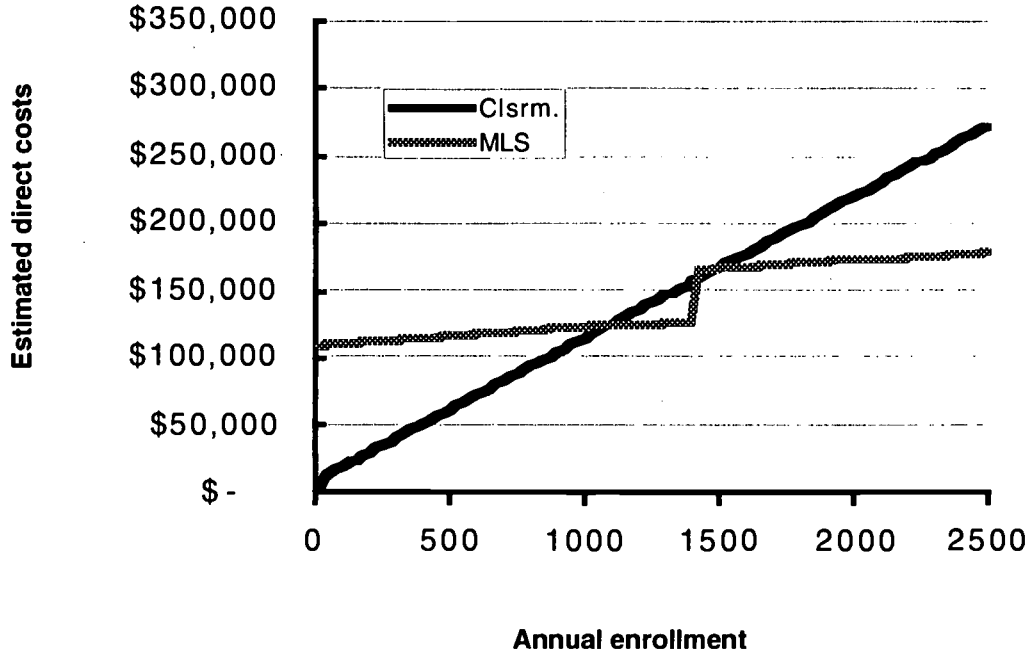
**Chart VIII—Intermediate Case, MLS Section (Enrollment=30, Classroom Section Enrollment=30)**




[11] The reported average section size across all MLS sections in fall 1996 was 29.

Finally, the Large Lab Case in Chart IX has MLS lab sections with an enrollment of 50. Note that the MLS cost curve has an even flatter slope than in Chart VIII because the incremental staffing cost declines again as section size increases. The curves first intersect at an enrollment of 1,000. At about 1,400 annual enrollments the need for an additional lab causes the MLS costs to shift up, but after that MLS costs are less than classroom costs.

**Chart IX–Large Lab Case, MLS Section (Enrollment=50, Classroom Section Enrollment=30)**



## Summary

Patterns emerge from the cost comparisons for the two instructional modes:

(a) At the lower levels of annual course enrollment, the costs of the MLS version of the course always exceed those of the classroom version. This occurs because of the fixed costs associated with the MLS course including the license fee and the costs of establishing and operating the initial MLS lab.

(b) The incremental (or marginal) costs of additional enrollments in the MLS course tends to be less than those for the regular classroom course (assuming instructor pay rates for the different course sections are the same). This result occurs because the MLS fee revenue offsets some of the course's staffing cost. Incremental costs are also reduced to the extent enrollment in the MLS sections is larger than in the classroom sections.

(c) Once enrollment grows to the capacity of the MLS lab, an additional lab must be added causing a step-up in MLS costs.

At the current levels of annual enrollments in remedial mathematics courses (about 1,000 students per year per campus), the direct costs of the MLS course with section enrollments of 30 exceed the costs of offering the instruction to students in the classroom course with enrollments of 30.

However, because the marginal costs of the MLS course tend to be less than those of the classroom version, with sufficient levels of annual enrollment and the appropriate combination of cost and fee factors, the MLS costs can be less than those of classroom courses. E.g., increasing MLS section size to 50 results in a crossover point at an annual enrollment of 1,000 students.

These results are dependent upon all the assumptions and estimates used in the cost model. A sensitivity analysis focused on the MLS section with 30 students, equal to the classroom section size, suggests that reducing the site license fee by half shifts the MLS cost schedule so that the crossover point is at an annual enrollment of approximately 2,000 instead of 2,500.

Another factor at work here is that the staffing costs for all of the remedial course sections are low because of the use of part-time faculty. The result is that any savings from increasing MLS section size are minimized because the staffing costs are small relative to the fixed costs of the MLS. Again, focusing upon the intermediate lab case shown in Chart VIII, holding staffing costs at $2,400 and increasing MLS section size to 35 results in a crossover point at an enrollment of 2,200. If section staffing costs are set at a higher rate (e.g., $7,750 based upon an average salary of $62,000 for full-time faculty and 8 courses per year), the crossover for MLS section size of 35 occurs at an annual course enrollment of 1,100. If MLS section size is increased to 50, the crossover occurs at an annual enrollment of 600.

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